



Microwave Imager Ocean Products in Preparation for NPOESS CMIS NRL and NOAA/NESDIS

**Karen St.Germain
Naval Research Laboratory, Remote Sensing Division
Washington DC**

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Evolution of Operational Microwave Imagers

	Polarization	SSM/I	SSMIS	WindSat	CMIS
85/91 GHz	Vert, Horiz	X	X		X
	3rd, 4th Stokes				
37 GHz	Vert, Horiz	X	X	X	X
	3rd, 4th Stokes			X	X
22/23 GHz	Vert, Horiz	X	X	X	X
	3rd, 4th Stokes				
18/19 GHz	Vert, Horiz	X	X	X	X
	3rd, 4th Stokes			X	X
10 GHz	Vert, Horiz	X	X	X	X
	3rd, 4th Stokes			X	X
6 GHz	Vert, Horiz			X	X
	3rd, 4th Stokes				
Spatial Resolution	37 GHz	27x38	27x38	8 x 13	TBD
Absolute Accuracy	Linear Channels	1.5	1.5	0.75	TBD



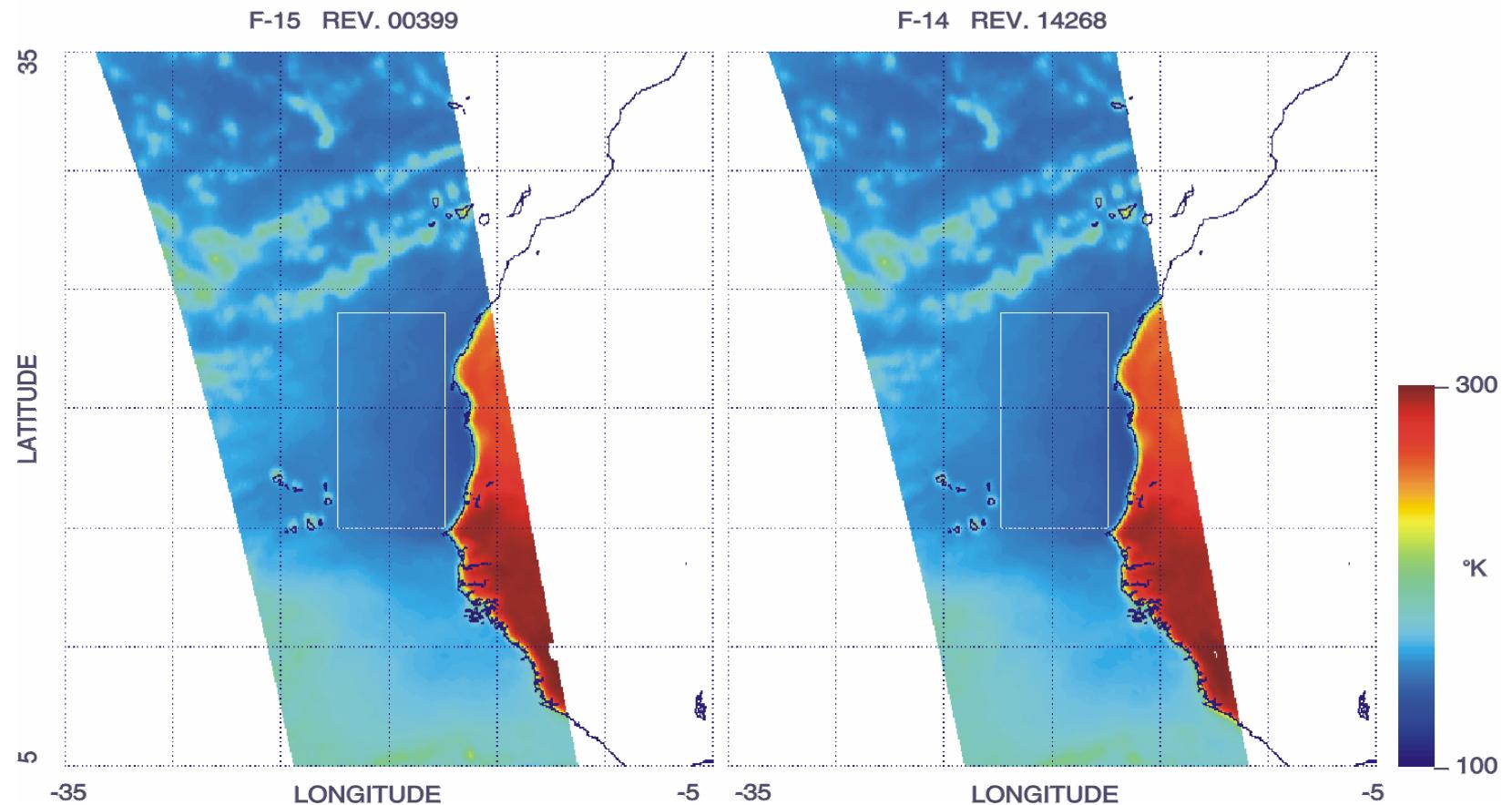
Current Operational Capabilities-DMSP

- **SSM/I Ocean Products**
 - 7 Channel Imagery
 - Wind Speed
 - Integrated Water Vapor
 - Integrated Cloud Liquid Water
- **SSMIS Ocean Products**
 - 24 Channel Imagery and Sounding
 - Above, Plus Atmospheric Vapor and Temperature Profiles
- **Algorithms Largely Empirical/Regression**



37 H Brightness Temperature

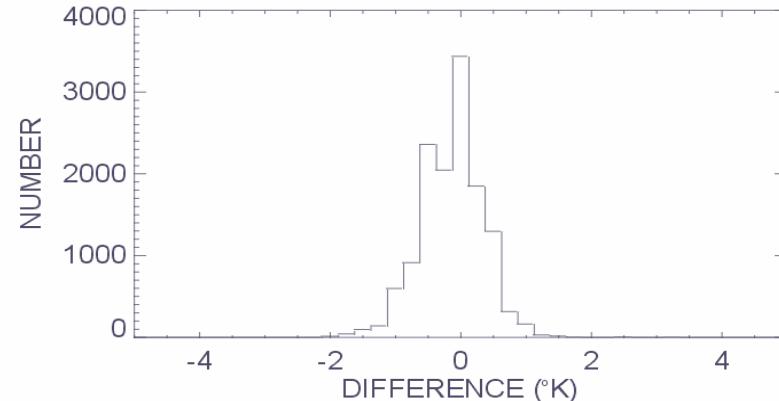
SSM/I F-14 and F-15 SDR COMPARISONS 37H





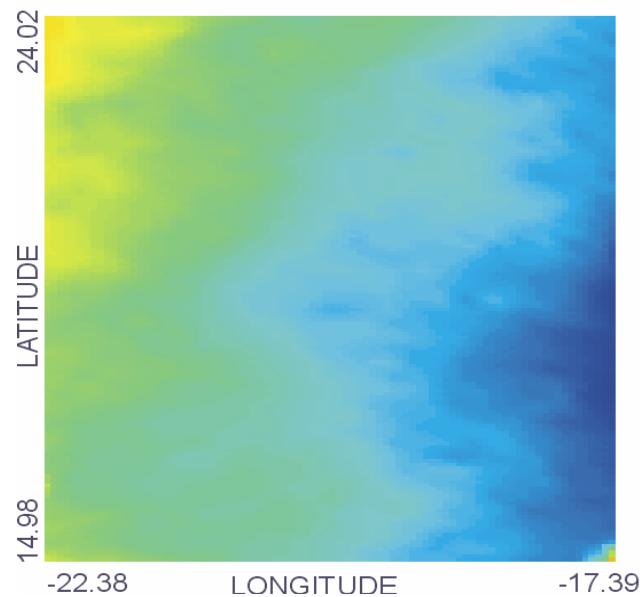
Inter-Sensor Comparison and Calibration

COMPARISONS FOR BOX REGIONS
F15 - F14 37H

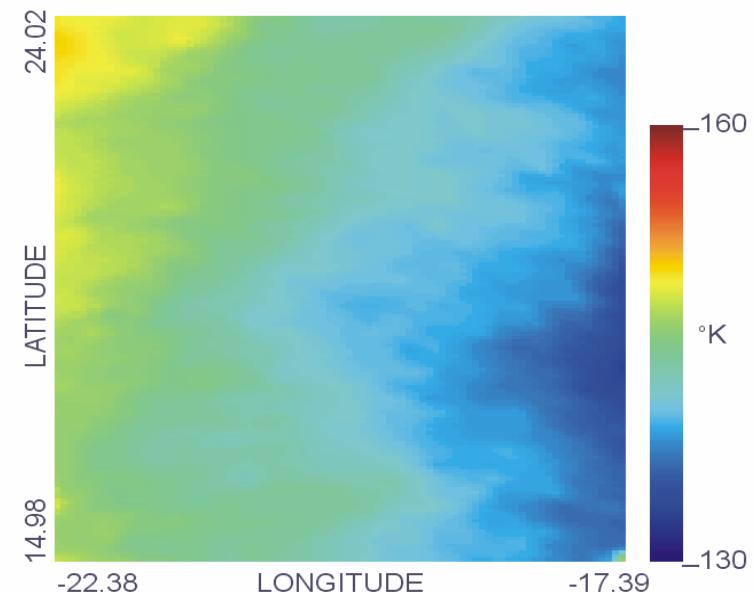


AVG DIFFERENCE = -0.03
STD DEV DIFF = 0.49
CORRELATION = 0.989

F15 - 00399

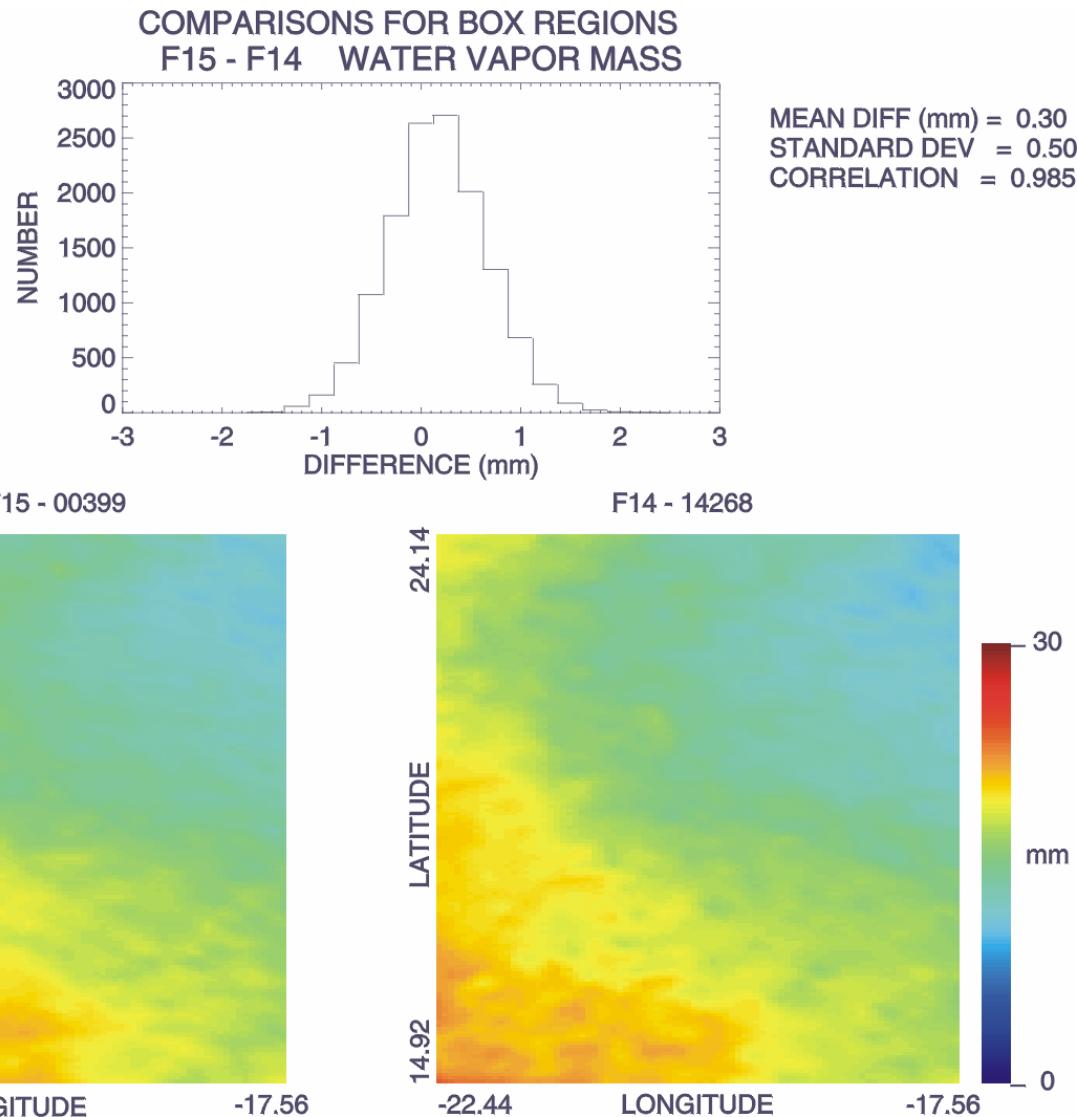


F14 - 14268





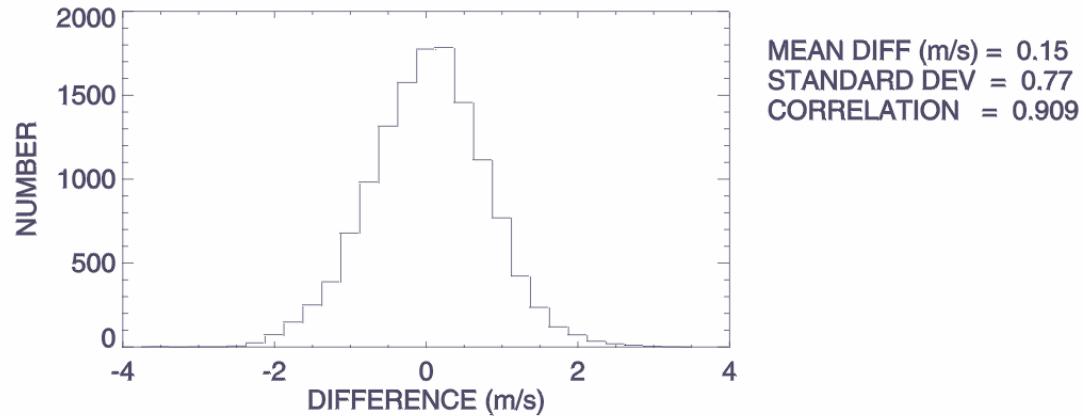
Integrated Water Vapor Inter-Sensor Comparison



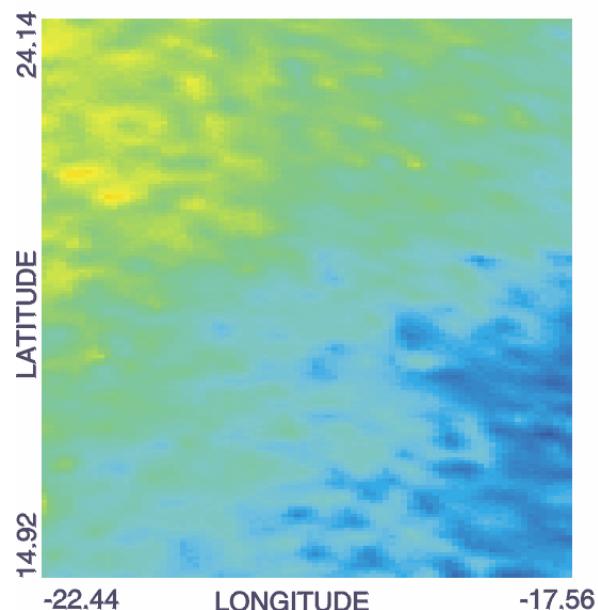


Ocean Surface Wind Speed Inter-Sensor Comparison

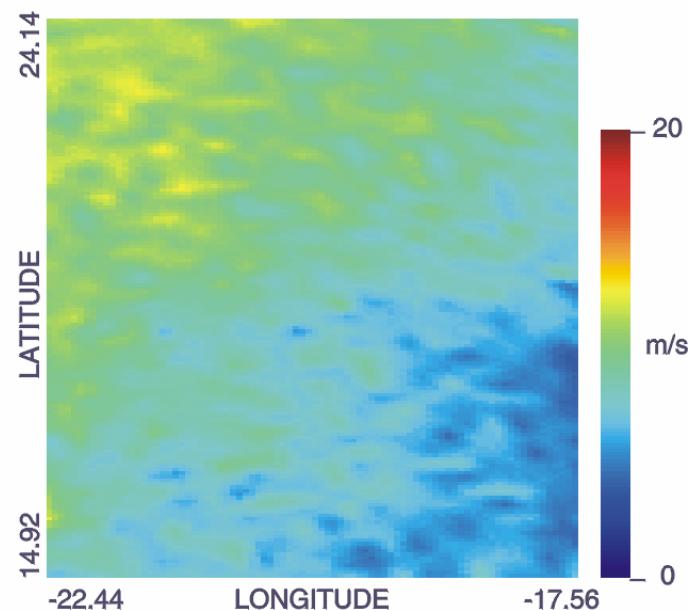
COMPARISONS FOR BOX REGIONS
F15 - F14 WIND SPEED



F15 - 00399



F14 - 14268





NPOESS New Capabilities:

Exploiting Low Frequency and Polarimetric Channels

- **Polarimetric Channels:**
 - Ocean Surface Wind Direction
 - Simultaneous Retrieval, Physically-Based Optimal Estimation
 - Simulation Results
 - 6 and 10 GHz Channels
 - Sea Surface Temperature
 - New Regression
 - TMI Results
 - New Polar Algorithms?



Polarimetric Radiometry

- Emission and Scattering Vary With Wind Vector (speed and direction)

- Wind Direction Dependence Arises From Anisotropic Distribution and Orientation of Wind Driven Waves

- Stokes Vector

- Polarization Properties of Emitted/Scattered Radiation

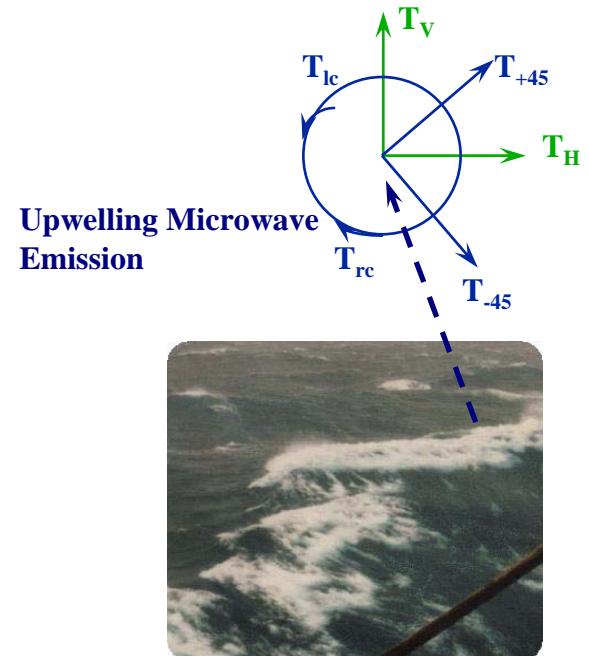
- Contains Directional Information

- Wind Direction signal is two orders of magnitude smaller than Wind Speed signal

- Two means of measuring

- Correlation of Primary Polarizations

- Direct measure of $\pm 45^\circ$, LHC, RHC



$$I_s = \begin{bmatrix} I \\ Q \\ U \\ V \end{bmatrix} = \begin{bmatrix} \langle E_h E_h^* \rangle + \langle E_v E_v^* \rangle \\ \langle E_h E_h^* \rangle - \langle E_v E_v^* \rangle \\ 2 \operatorname{Re} \langle E_v E_h^* \rangle \\ 2 \operatorname{Im} \langle E_v E_h^* \rangle \end{bmatrix} = \begin{bmatrix} T_v + T_h \\ T_v - T_h \\ T_{45} - T_{-45} \\ T_{lc} - T_{rc} \end{bmatrix}$$

Available from “Dual Polarization” Systems
(SSM/I, SSMIS)

New Capability Available from “Polarimetric” Systems
(WindSat, CMIS)



Fundamentals of Retrieval Technique (Optimal Estimation)

Let:

y = Measurement vector, with corresponding covariance matrix S_y .

x = True distribution of geophysical parameter to be retrieved.

x_a = *A priori* distribution of x with covariance S_a .

\hat{x} = Retrieved distribution.

If the measurement and *a priori* errors are normally distributed, then the maximum likelihood estimate of the true distribution, , is obtained by minimization of the cost function

$$\Phi = (\hat{x} - x_a)^T S_a^{-1} (\hat{x} - x_a) + (y - F(\hat{x}))^T S_y^{-1} (y - F(\hat{x}))$$

Where F is the forward model operator, $y = F(x)$.



Application to WindSat Retrieval Problem

- Forward Model, F:

- Current: ocean surface emissivity model, atmospheric model (dry air, and water vapor components)
- To be added: clouds and precipitation, foam

- Measurement Vector, Y:

$$\begin{array}{ll} T_v(6.8) & T_h(6.8) \\ T_v(10.7) & T_h(10.7) \quad T_3(10.7) \quad T_4(10.7) \\ T_v(18.7) & T_h(18.7) \quad T_3(18.7) \quad T_4(18.7) \\ T_v(23.8) & T_h(23.8) \\ T_v(37) & T_h(37) \quad T_3(37) \quad T_4(37) \end{array}$$

- State Vector, X:

- Current: wind speed, wind direction (u,v), precipitable water vapor (V), sea surface temperature (SST)
- To be added: cloud liquid water, rain rate, foam fraction

- Minimize Cost Function to resolve ambiguities



Simulation Model vs. Retrieval Model

Simulation Model

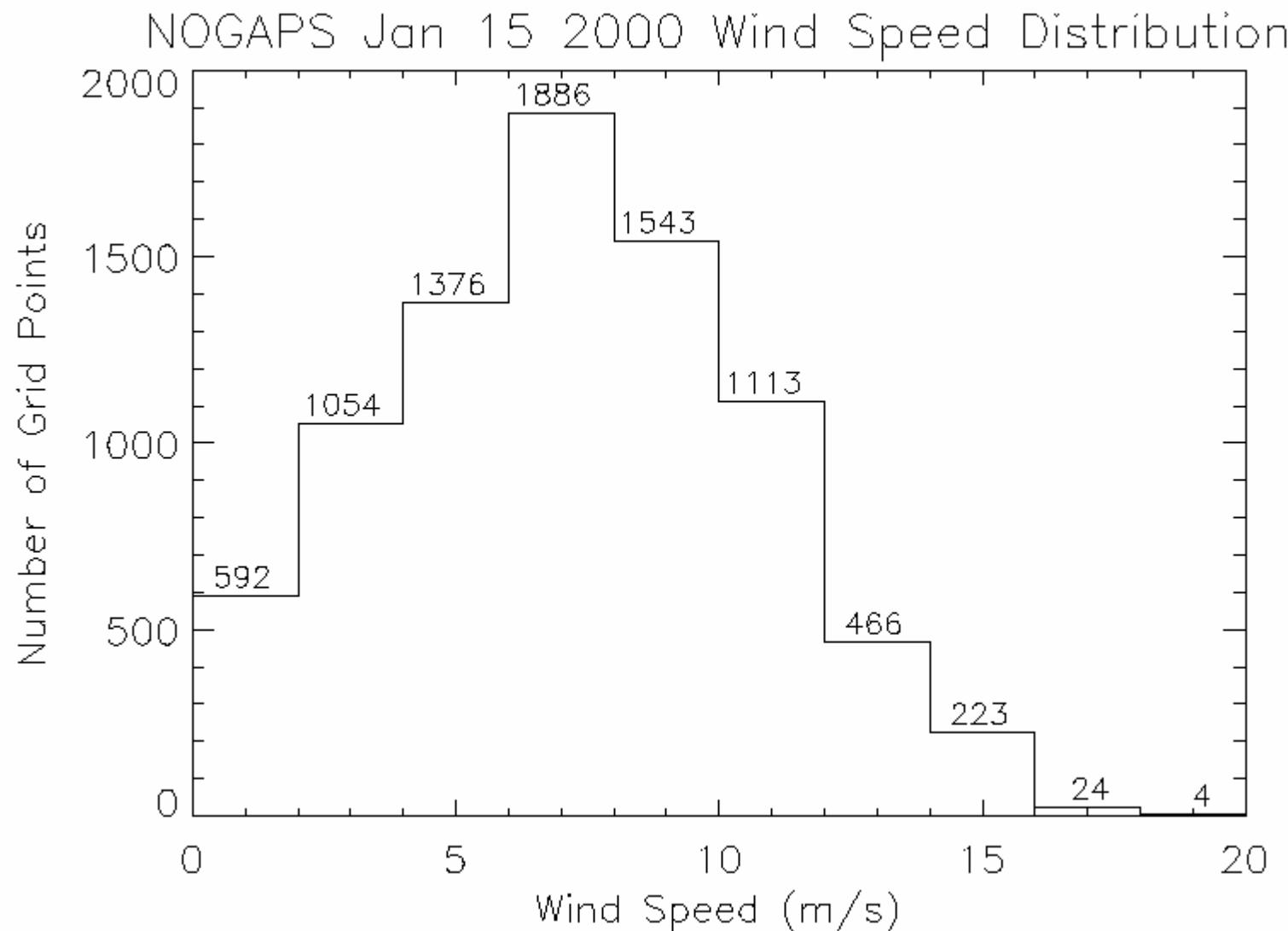
- Atmospheric terms are calculated by stratifying the atmosphere in 1 km altitude bins
 - T_{atm_up}
 - T_{atm_down}
 - $e^{-\tau}$

Retrieval Model

- Atmospheric terms are approximated as column weighted averages
 - $\langle T_{atm_up} \rangle$
 - $\langle T_{atm_down} \rangle$
 - $e^{-\tau}$

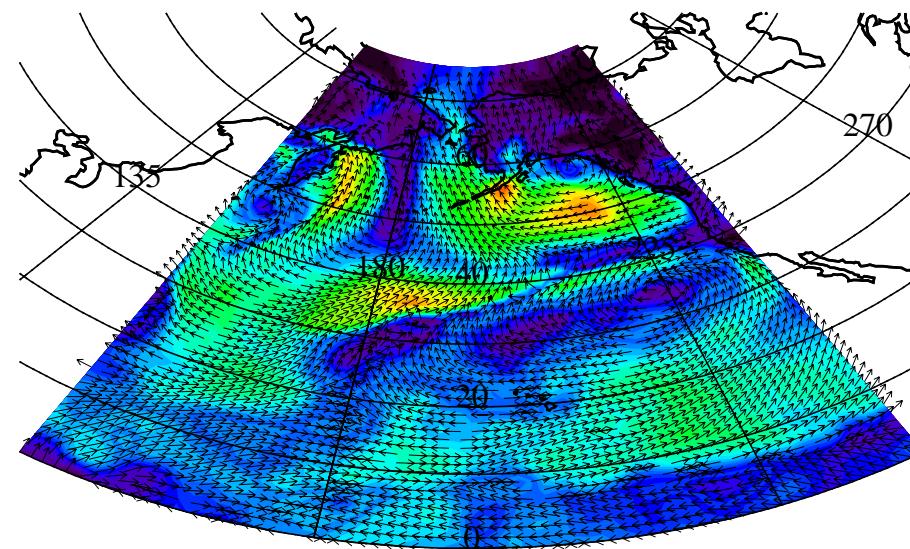


Development Data Set

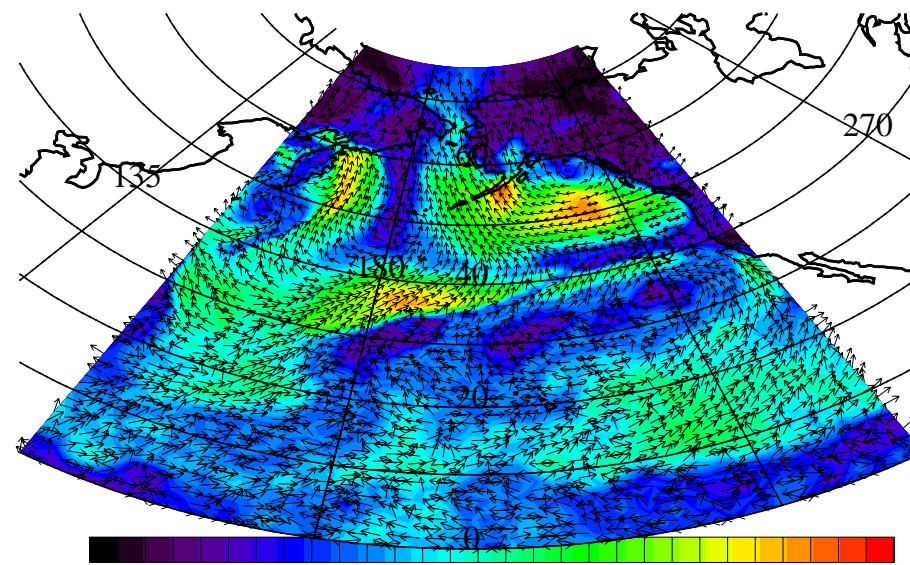




True Wind Velocity (ms^{-1})

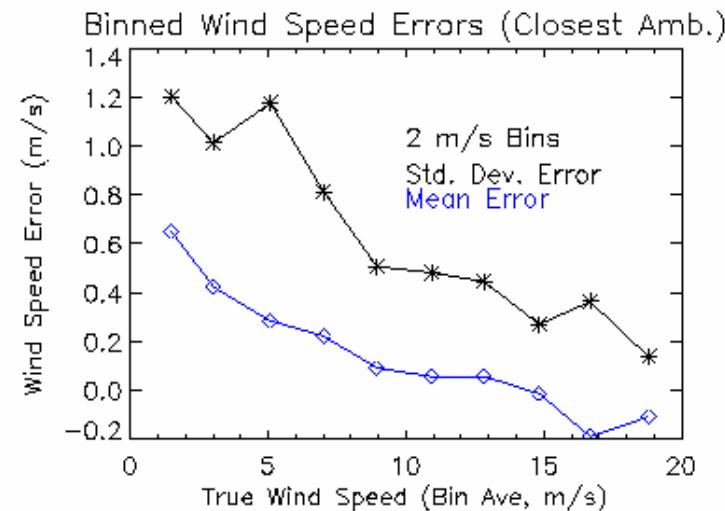
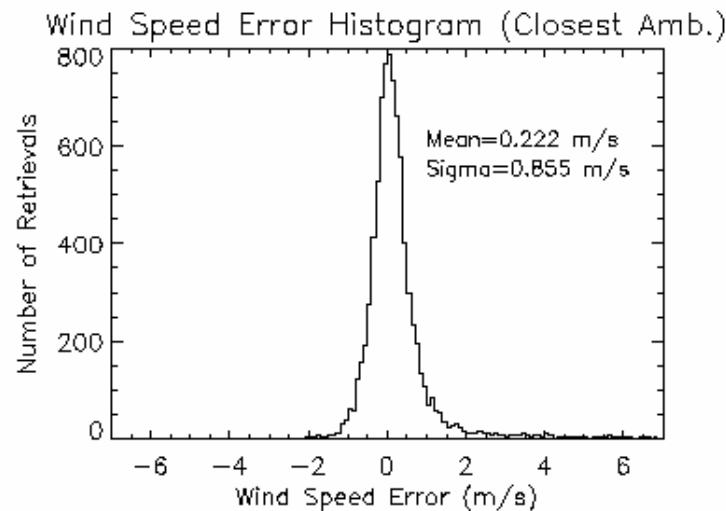
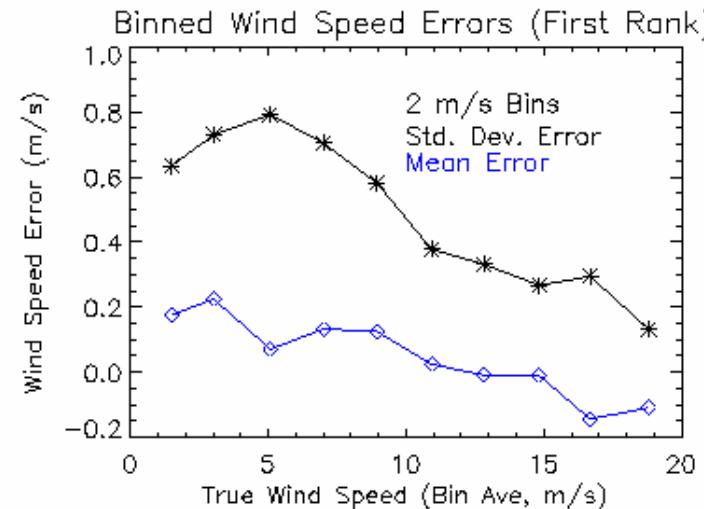
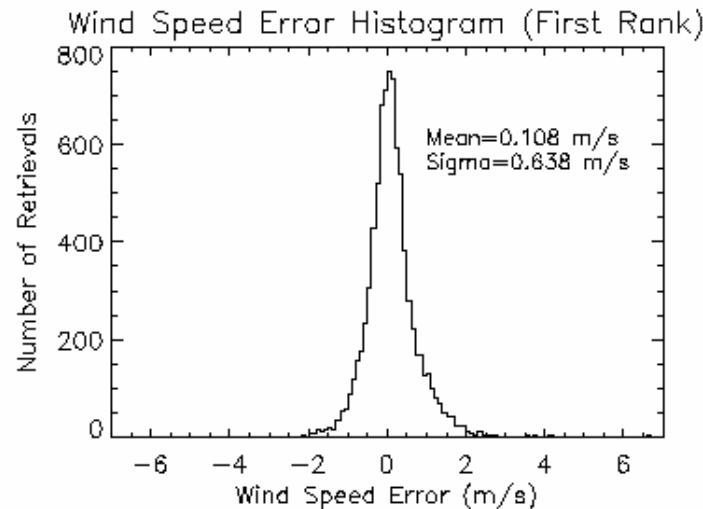


Retrieved Wind Velocity (ms^{-1})



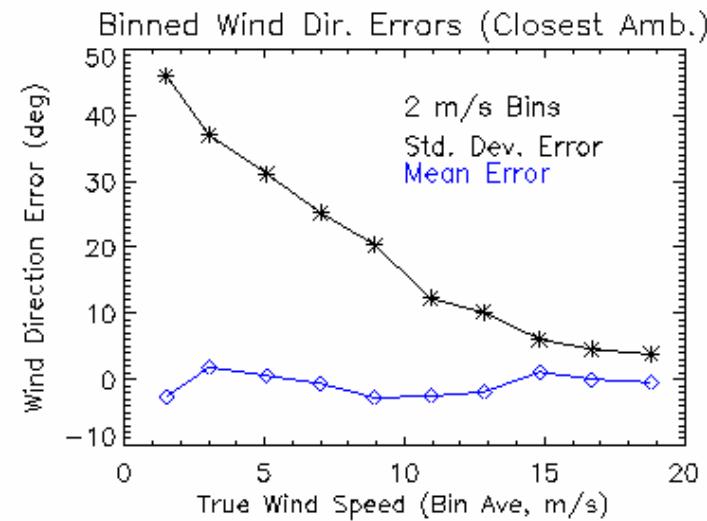
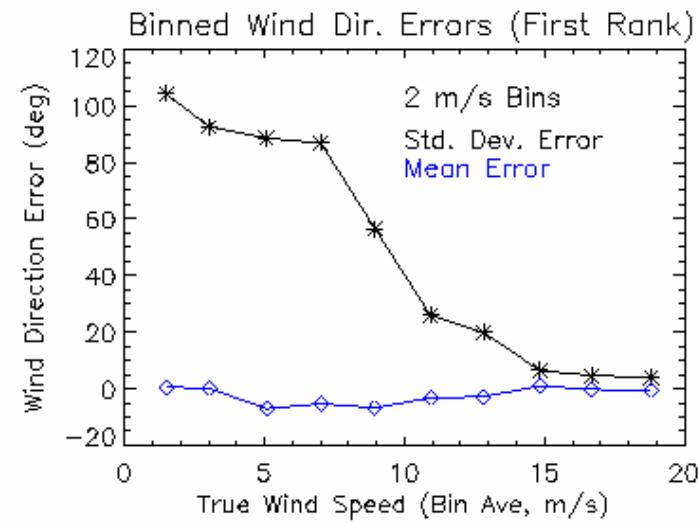
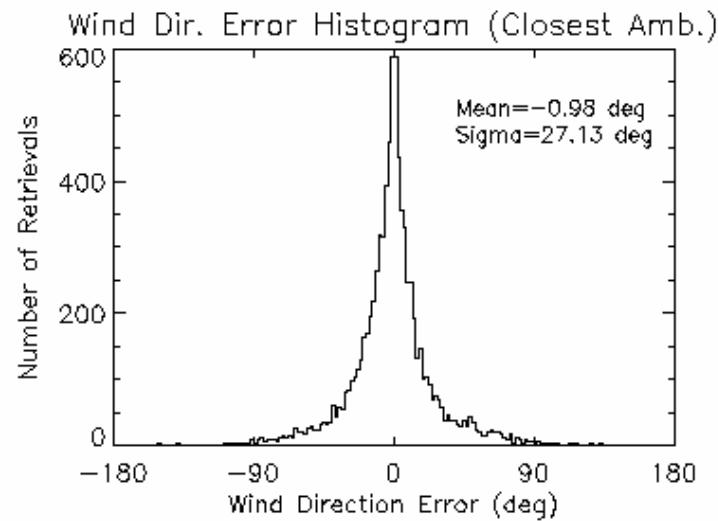
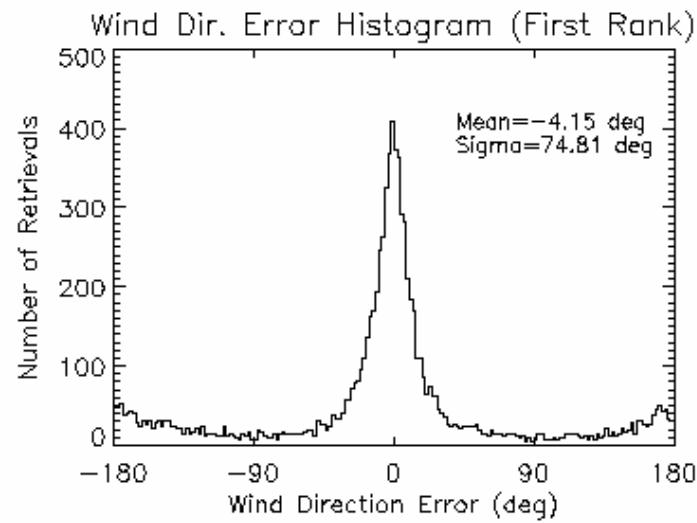


Wind Speed Retrieval



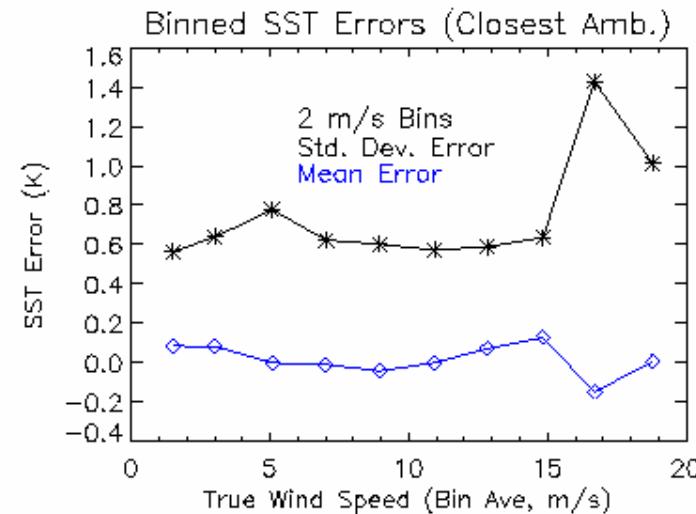
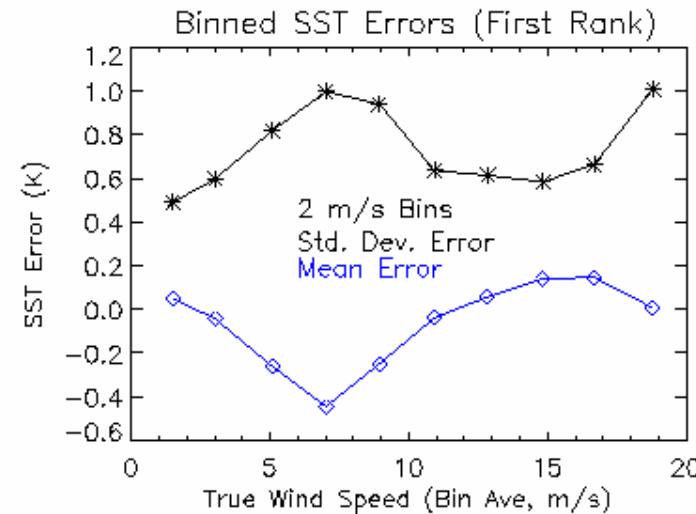
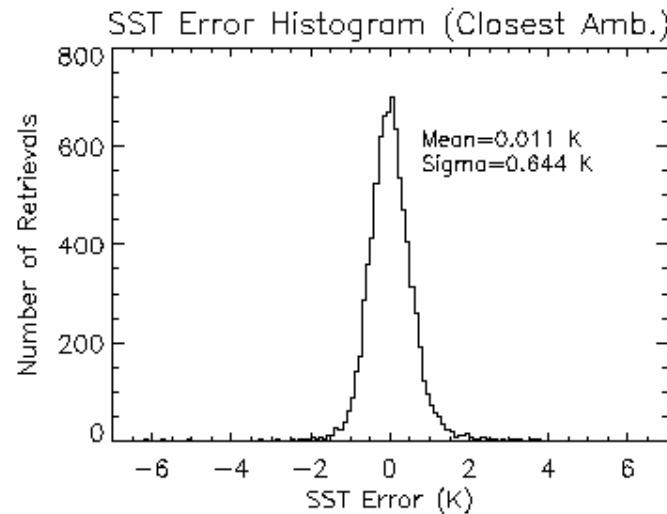
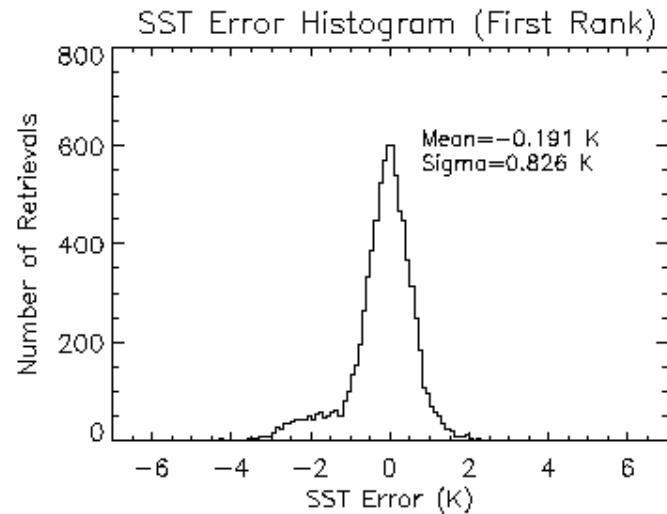


Wind Direction Retrieval



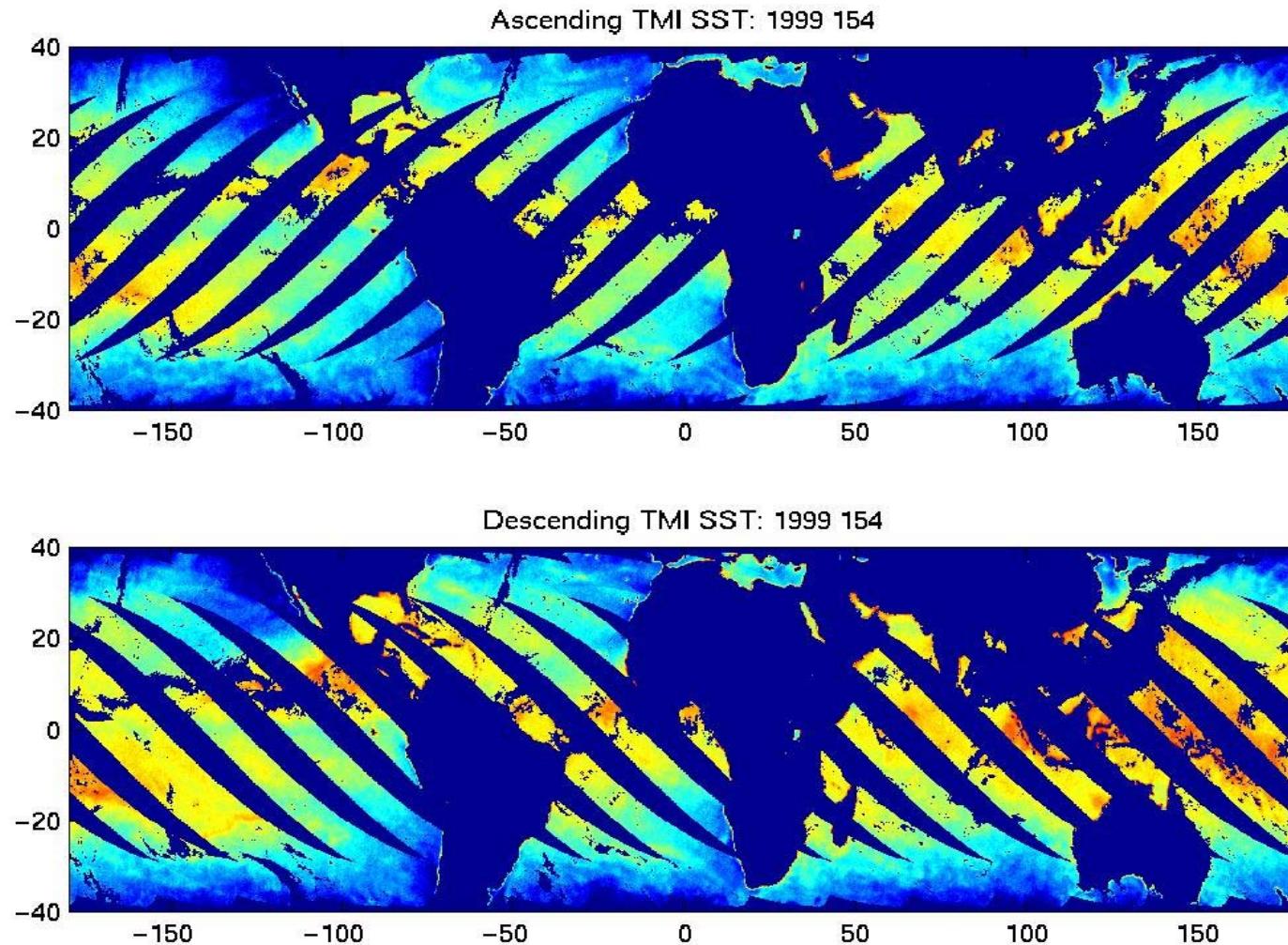


Sea Surface Temperature Retrieval



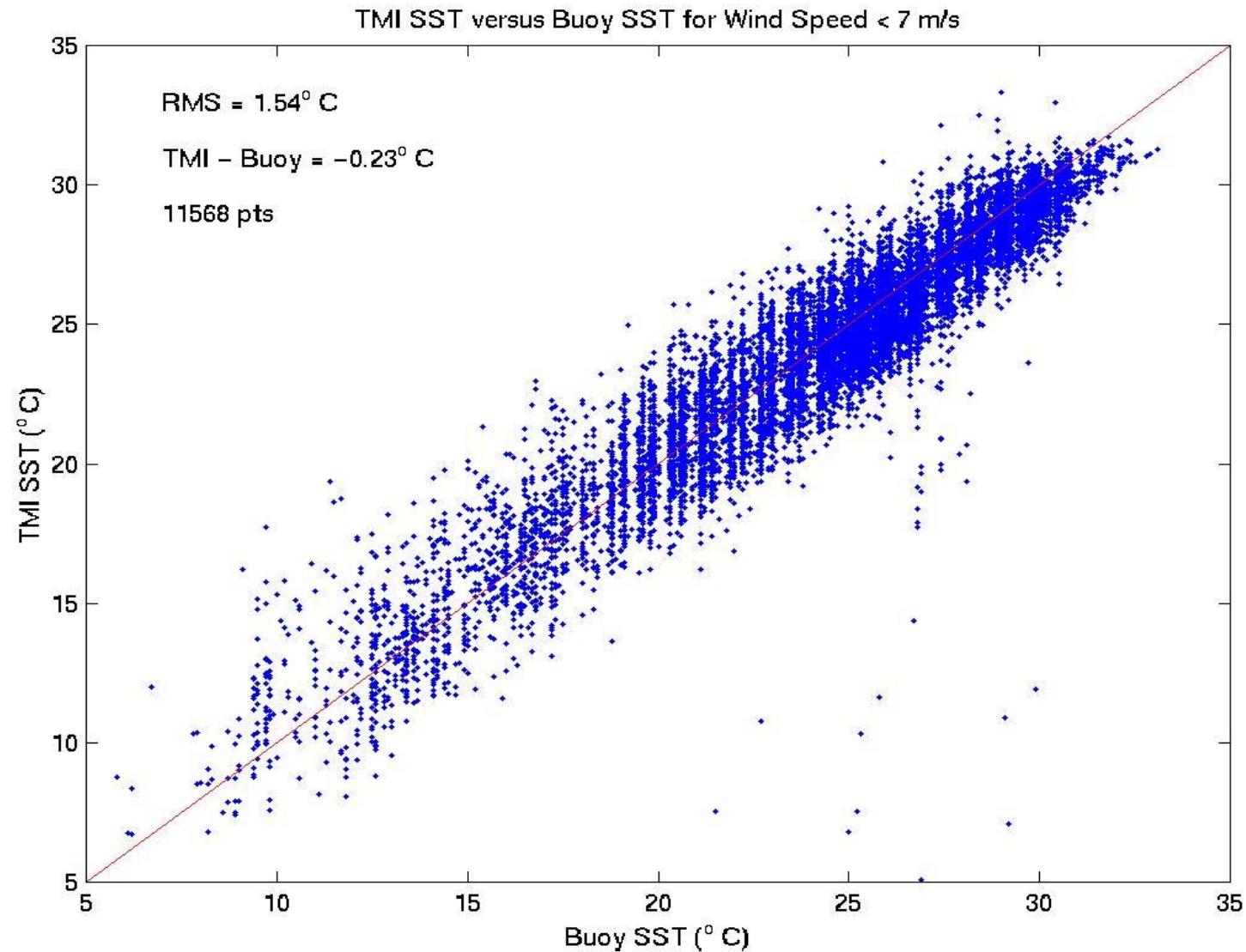


Sea Surface Temperature Retrievals Regression Algorithm



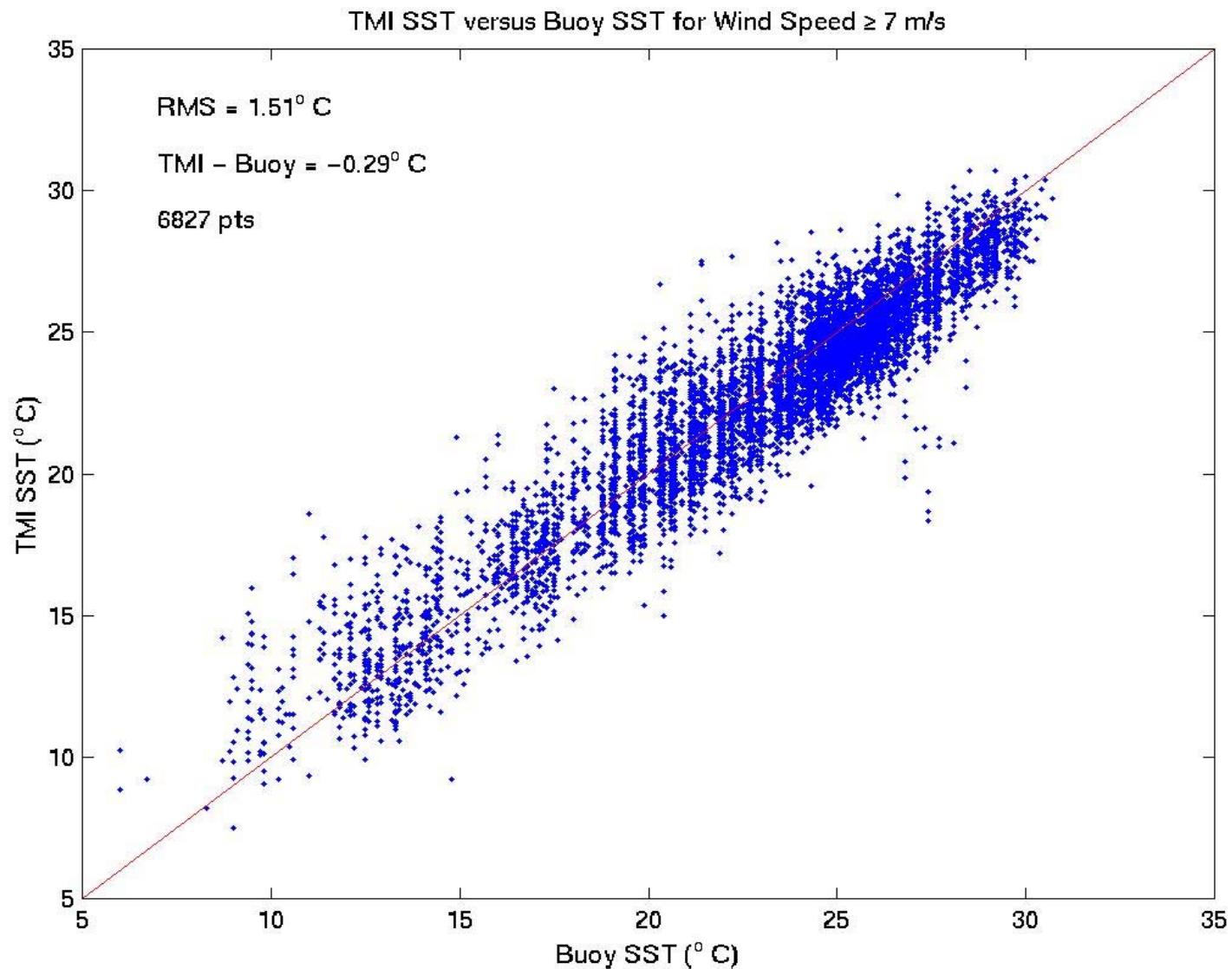


SST Retrieval – Low Wind Speed





SST Retrieval – High Wind Speed





New and Improved Polar Products?





Initial Polarimetric Measurements

- **Field Campaign**
 - **10 GHz polarimetric measurements**
 - **October-November 2001**
 - **USCGC Healy**
 - **Berents Sea**
 - **Collaborators**
 - **Jet Propulsion Laboratory**
 - **Naval and National Ice Center**
 - **Technical University of Denmark**



10 GHz Radiometric Observations

- Thin ice types
 - With/Without frost flowers
 - With/Without Snow
- Pancake ice
- First year ice
 - Smooth
 - Deformed
 - With/Without Snow
- Multiyear ice

